Real-Time Onboard Global Nonlinear Aerodynamic Modeling from Flight Data

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Purpose

The objective is to develop flight test techniques and nonlinear mathematical modeling techniques for efficiently identifying airplane aerodynamic models over a large flight envelope, based on flight data alone. The Phase II research is focused on further development of the system identification routines and test techniques to enable nearly real-time aerodynamic model estimation during flight.

Background

Mathematical models are required for analysis and understanding of any physical system. One challenge with designing and testing aircraft that are operating over large flight envelopes or are unconventional in design is the identification of proper models and model structure. The aerodynamic characteristics may be functions of many variables and vary in nonlinear and possibly time-dependent ways. The current state-of-the-art for nonlinear aerodynamic model structure determination involves selection of terms from a pool of postulated modeling terms, sometimes in an iterative fashion, based on data transformations and statistical modeling metrics computed from the data. In this research, advanced modeling techniques using fuzzy logic will be developed to advance the state-of-the-art in nonlinear aerodynamic modeling in a way that does not require specification of candidate modeling terms. The ability to model the nonlinear behaviors that exist due to separated aerodynamic flow, structural / propulsive / aero / flight controls interactions, mass properties changes, etc. is absolutely critical to the successful and efficient development of future novel airplanes that will be needed to fulfill the goals of increased performance for N+3 aircraft and beyond. This is a key component in the "Learn-to-Fly" concept, where the intent is to autonomously develop vehicle characterization up through the ability to fly a vehicle with minimum human interaction and time. The ability to rapidly update simulation tools (either aerodynamic models, or flight response models) based on flight test will be improved with successful outcome of the program applicable to both piloted and autonomous vehicles. This research was started during the Phase I research, and the fuzzy logic system identification process developed was shown to be a powerful technique for developing models of the nonlinear aerodynamic behaviors. To enable autonomous vehicle characterization, the modeling process needs to be done rapidly and model updates need to be conducted during flight rather than waiting for post-flight analysis.